

Teammates and Trainers: The Fusion of SAF's and ITS's

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ABSTRACT *SYNTHERS are cognitive agents that perform the job of a team member, or any other role external to the team, that normally requires a human role-player or trainer to enable team training. We are conducting a set of psychological training experiments in which teams are being trained in a military command and control task with confederates who play the roles of SYNTHERS. By using confederates, we were able to rapidly define, assess and evaluate the requirements for simulated teammates, and the relative contributions of certain components, such as performance measurement and on-line feedback, to training outcomes. Based on our experiments, we believe that SYNTHERS, when functioning both as teammates and as Intelligent Tutoring Systems, will not only reduce the cost of training, but also result in increased training effectiveness.*

1. Introduction

Team training increasingly takes place in synthetic environments. However, such training is often still modeled after live team training, resulting in a very cost-intensive process in terms of both the time and resources required. Specifically, gathering all of the team members, instructors, and support personnel to conduct the training is very costly, and does not even include the costs involved with the lost productivity associated with the other tasks that those personnel are not doing while helping other teammates practice or while practicing themselves [1]. This issue becomes even more salient in cases where large-scale training of distributed teams is involved. For instance, the exercise "Unified Endeavor" required 470 role-players with a total of 981 operators/controllers. These numbers are simply

prohibitive in today's climate of decreasing military budgets and manpower.

We believe that the development of synthetic teammates, or 'SYNTHERS', is a promising alternative to training with all human teammates and role-players. SYNTHERS are cognitive agents that perform the job of an unavailable team member, or any role external to the team that normally requires a human role-player or trainer to enable training or teamwork practice. We believe that they are promising, since SYNTHERS may always be available, may be modeled after experienced training personnel, and may therefore be more cost effective in the long run.

The research challenge lies in keeping the advantages associated with human teammates, while minimizing or eliminating the disadvantages. Thus, SYNTHERS should display the same collaborative and cooperative behavior typically associated with human teammates, while

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reducing some of the negative aspects of training with live teammates, such as the relative unpredictability of their behavior and their fluctuating availability for team training. When these research challenges are met, we believe that SYNTHERS will not only reduce the cost of training, but will even result in increased training effectiveness.

However, there is a gap that has to be bridged between this conception of SYNTHERS and current implementations of computer generated forces. A recent National Research Council report [2] identified that a shortcoming in the area of military simulations is the lack of behavioral realism in computer generated forces (CGF's). Most synthetic force models within military simulations have been constructed using relatively primitive human models in which the richness of behavior and decision-making are represented in only a coarse and brittle manner. This has produced simulated forces with unrealistic behavior and simplistic responses that do not correspond to the behavior of real individual soldiers and units [2],[3].

Therefore, in order to fulfill the objectives of our SYNTHERS, there is a need for improvement in the behavioral representation of CGF's. Part of this improvement will come through the development of new architectures for cognitive modeling. However, even if very powerful architectures existed for the modeling of SYNTHERS, the question would still be what behaviors they should exhibit.

The question of required behaviors is probably one that cannot be answered in general; Chandrasekaran and Josephson [4] argue that what a cognitive model needs to contain is vitally affected by what kinds of questions one needs to answer, i.e. the goals of the simulation. Therefore, the fidelity of the model must be judged by the needs of the model user. They describe a research strategy in which the requirements of models are empirically investigated. Our approach towards the definition of SYNTHERS as teammates for team training has been somewhat along those lines. The goals of this research are threefold:

- To define empirically validated requirements for SYNTHERS for team training. The emphasis is not just on defining requirements but also on the empirical validation of those requirements: we would like to know what the relative contribution of certain SYNTHERS requirements is in terms of training effectiveness.
- To develop guidelines for the development of plausible cognitive models.

- To develop guidelines for scenario development including role players and/or SYNTHERS.

2. Research Approach

In our approach to this problem, a set of psychological training experiments is being carried out, in which teams are being trained with simulated teammates [5]. However, these simulated teammates are not executable models of intelligent agents. Instead, we chose an approach in which humans, confederates to the experimenter, play the roles of the simulated teammates. By using confederates, we are able to rapidly assess and evaluate what the requirements of the simulated teammates should be, and what the relative contributions of certain components of the simulated teammate add to the training outcome, both quantitatively and qualitatively. We are not just interested in defining requirements for synthetic teammates, but even more in the empirical validation of those requirements. The use of a number of different measures adds to the strength of the approach. Using human confederates instead of software models at this point in the research process has a number of advantages. The most obvious one is that it is easier, and cheaper, to change the behavior of human confederates through scripts than to redesign a software model. Thus, in working with confederates we have chosen for a relatively low-cost approach for testing proposed requirements for SYNTHERS. Defining empirically validated requirements for SYNTHERS is still in its early stages. Proposed requirements still need extensive evaluation and will probably need to be altered based on these evaluations. Therefore the costs of developing software models at this point outweigh the benefits. Second, training experiments with human confederates aid the exploration of other factors of interest in the development of SYNTHERS for team training, such as personality variables and factors such as facial expressions, speech intonations etc. [6].

The testbed that we use is a modified version of the Dynamic Distributed Decision-Making (DDD) simulation. This computerized task (see Figure 1) simulates a military command and control task in which a team of decision makers, each of whom controls specialized sub-platforms, needs to enforce a "demilitarized zone". This demilitarized zone is threatened by an enemy, but is also traversed by friendly ground vehicles and aircraft. The goal of the team is to identify the nature of all vehicles and aircraft (i.e., friendly versus enemy) that encroach or enter the demilitarized zone, and then to attack enemy targets that enter this zone, while not harming any friendly vehicles and aircraft. The DDD simulation was initially developed by Serfaty and Kleinman [7], and has been used in a

variety of contexts and for a variety of research questions, including optimizing team organization, optimizing team decision making, and team training.

The DDD is flexible, in that the number of team members, the lay-out of the area, the allocation of sensors and weapons, and control over the timing, heading, path and number of targets approaching the demilitarized zone, are under the experimenter's control. In addition, DDD offers numerous opportunities for the experimenter to automatically measure team performance on a number of dimensions.

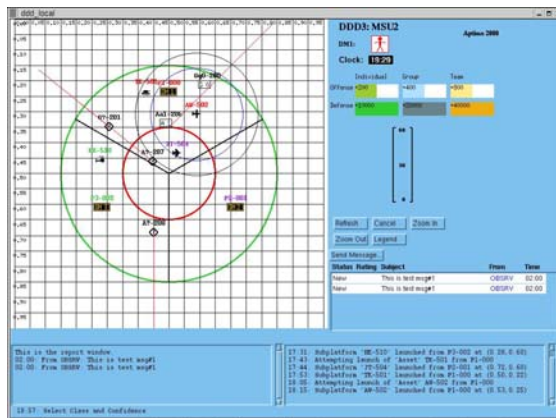


Figure 1. The DDD testbed

In our initial experiments, we are using a three-person team adaptation of the DDD. This team consists of two confederates, and one subject to be trained on teamwork skills. The subject is not aware of the fact that the other two team members are in fact confederates. The confederates act according to a tight script, and their task varies over the experiments from just providing opportunities for practicing teamwork skills, to modeling those skills, and providing coaching and feedback, or combinations of those behaviors. This situation will be contrasted with a situation in which three naïve subjects are brought into the experiment, reflecting the “classical” situation in which someone is being trained with his/her fellow trainees. Although the DDD can be made sufficiently realistic for military personnel to exhibit their skills, we are using university undergraduates as subjects. This enables us to carry out the experimentation in a relatively limited amount of time.

3. Results

We started our research by defining a framework for training teams with synthetic teammates. In recent years, it has been shown that a good approach to training teams with complex training technology is linking training goals to events in training scenarios in a controlled fashion.

This is called the ‘event-based approach to training’ (EBAT)[8]. The primary goal of EBAT is to systematically provide opportunities for a training audience to develop critical competencies by receiving practice in simulated environments that are representative of actual operational conditions, and receiving feedback linked to specific events that occur during training. EBAT tightly links trainee needs, critical tasks, learning objectives, scenario design, performance measurement, and feedback. The general assumption of EBAT is that without a systematic linkage among these components there is no way of knowing or ensuring--with any degree of certainty--that the exercise training will have its intended effect.

Figure 2 shows how the EBAT framework supports the design, development, execution, and evaluation of exercises.

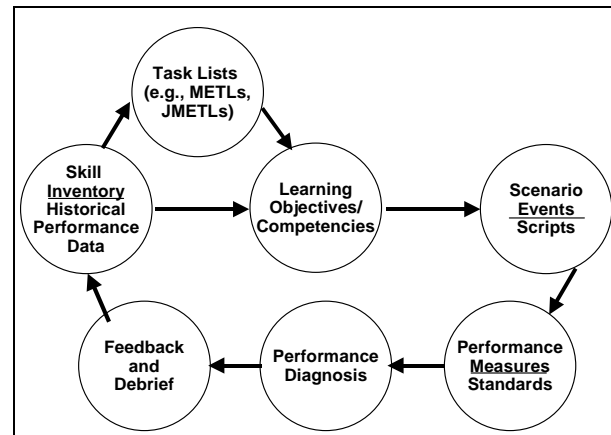


Figure 2. Components of an EBAT Framework. Adapted from [9]

The EBAT-approach provides a good starting point for the development of a conceptual framework for training teams with synthetic teammates. It shows us where synthetic teammates could possibly play a role in training teams: they could act as fellow teammates, as collateral forces, or as enemy forces. Second, it shows that, as much as scenario events are scripted, synthetic teammates should behave in a scripted manner, too. This does not mean that their behavior has to be strictly ‘canned’, and predictable for the trainee, but it does imply that their behavior is predictable for the scenario designer.

The results of our initial analyses show that at least three design components can be distinguished for simulated teammates:

1. A task component: the level of proficiency in the task the simulated teammate should have. Our analysis shows that simulated teammates do not necessarily have to be experts in the task, but should master the task to such an extent as to be believable and useful teammates in a team training context. This will

probably involve some level of both taskwork (the knowledge and skills involved in carrying out the individual task) and teamwork (the knowledge and skills involved in cooperating with others) [10]. An analogy from the sports arena will help to clarify this issue. Tennis instructors, playing and practicing with you from the other side of the net, do not necessarily have to be expert players to provide you with the right shots to practice your skills. Along similar lines, simulated teammates do not necessarily have to be at an expert-level of proficiency in the task to provide valuable instruction and practice opportunities. In fact, our data show that our confederates are not playing at an expert-level of proficiency: when they are allowed to play the DDD in a free-play situation, they perform much better than when they are playing the confederate-role.

It is impossible to script the behavior of the simulated teammates for every target in the scenario. It would result in very unrealistic behavior with the same “brittleness” that is criticized in current CGF’s. Therefore, we decided to define a set of “standard behaviors”. For the DDD testbed, we defined the task component as:

- The synthetic teammates staying in a predefined area of the screen, unless called upon by the trainee or by the script.
 - The synthetic teammate playing the game in a normal fashion: detecting, identifying, and engaging targets that would appear in their area.
 - The synthetic teammates not communicating unless they had to (when there was a target in their area for which they lacked the attacking power), or when they were asked a specific question.
 - The synthetic teammates obeying the requests from the trainee.
 - The synthetic teammates following a time-based script, in which they would take certain actions (verbal or game-based) upon certain targets or their sensor and weapon systems. The events in the scripts are related to the instructional/practice component described in the next paragraph.
2. An instructional/practice component: what are appropriate instructional and practice strategies for this teammate to exhibit. One of the most important features and potential benefits of training with simulated teammates is that they can demonstrate certain behaviors in training and provide systematic and structured opportunities for practice. For example, providing backup to other team members in case they become overloaded is regarded as an

important teamwork skill [11]. In situations where you are being trained in an expert team, however, members do not become easily overloaded, and the opportunities for practicing this teamwork skill are rare. However, in training with a simulated teammate, these opportunities do exist, because sythetic teammates can be specifically scripted to become overloaded through a combination of external events, and the reaction of the simulated teammate to this situation. Therefore, training with simulated teammates provides the trainee with excellent opportunities for practice that might hardly exist otherwise.

The events in the scripts that would result in opportunities for practice were based on a cognitive task analysis of supporting behavior in the DDD. In one of our initial experiments, we focused on the training of supporting behavior, which consists of three components:

- Providing backup to other teammates when they become overloaded
- Requesting backup in situations in which you become overloaded
- Catching and correcting errors before they have negative consequences on the teams’ performance.

A cognitive task analysis focused upon these three components, and when and how they would show up in the DDD. By carefully observing both expert and relatively novice players, we observed, for example, that the following errors are quite ‘natural errors’ in the DDD:

- Attacking an enemy in the neutral zone
- Relying on incorrect identification data and therefore attacking targets mistakenly
- Prioritization errors: giving priority to targets which are still less threatening than other targets, since they are further removed from a predefined no-fly zone.
- Attacking with a weapon system which is out of ammunition.

The scripting of these ‘natural errors’, in combination with the “standardized behavior” as described in the previous paragraph, resulted in believable SYNTHES behavior. The data show no indication of participants who questioned the realism of the SYNTHES. This can be taken as evidence that SYNTHES in this context do not have to perform at an expert level, and can be scripted without being predictable or believable for the trainee.

3. A performance measurement/feedback component: Our research has led us to question whether it will be possible to measure teamwork skills on-line and

automatically in dynamic environments. The results show that this is possible to some extent, at least in the environment that we are currently working in, the DDD simulation. The generalizability of these results to real-life military environments is something which still needs to be addressed.

4. Implications

One of the implications of this line of reasoning is that we propose a layered model of scenario events for defining the behavior of synthetic teammates in team training. The first layer consists of the 'normal' scenario events that occur: the behavior of entities external to the team (such as a target approaching with a certain speed at a certain altitude).

A second layer consists of the behavior of the synthetic teammate(s): How should synthetic teammates behave during these events? For example, if the training goal is to learn about providing backup to another team member, the training exercise must create an opportunity to provide backup. In the DDD this can be done by sending a wave of targets to one simulated team member -- too many to act upon by him/herself --, and have this teammate ask for help. However, this opportunity for providing backup will probably only be noticed by the trainee if he/she is not also overloaded. Therefore, we have to manipulate the scenario to ensure that our trainee is not overloaded. Finally, we can make the cue for providing backup even stronger if it is clear to the trainee that the third teammate on the team cannot help out; for example, since most of his/her weapon or sensor systems have run out of ammunition or fuel.

A third layer consists of training strategies linked to team performance measurement and providing on-line feedback.

All three layers are connected by their relationship to training objectives/competencies, but they will each contribute to achieving these goals in different ways. The first layer defines events external to the team. The second layer defines when and how the synthetic teammates will provide opportunities for training certain (teamwork) skills. The third layer defines how intelligent performance evaluation and on-line feedback could be provided by a synthetic teammate. The three layers can be linked in various ways: by time (when will a certain event at each of the three layers occur), by the contingency of events (e.g., the synthetic teammate will provide an opportunity for practicing error correction at specific targets), or by a combination of both.

Another important implication of this conceptual framework and supported by empirical results, is that

synthetic teammates do not necessarily have to behave as experts in the task. By redefining SYNTHERS as entities that serve certain training goals, their role is not necessarily one of being a 'normal', proficient teammate. Therefore, the mission of synthetic teammates could be to provide opportunities for practicing certain skills, instead of being expert performers in the task itself. It is important to put the trainee in the center of attention, and not so much the SYNTHER, since their goal is just to help train the trainee.

5. The road ahead: SYNTHERS: fusion between SAF and ITS

Our research focuses upon empirically validated requirements for SYNTHERS in team training. The initial driving force behind this research was the idea to have SYNTHERS fill in the roles of missing teammates in team training. However, in the course of the research, it became clear that SYNTHERS have more to offer. They can be assigned various roles: as teammates, as collateral forces, or as opposing forces. More interestingly, they can be assigned a role in the training process itself. They can act as coaches, who provide opportunities for practicing certain skills, and can have a role in diagnosing, evaluating, and remediating trainees' knowledge and skill. Through the integration and fusion of SYNTHERS as SAF's and SYNTHERS as ITS's, we will be able to explore a new dimension of learning companions[12], and pedagogical agents [13].

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